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Layton-Matthews, Kate; Grotan, Vidar; Hansen, Brage Bremset; Loonen, Maarten J.J.E.

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# Density dependence in an aging and declining population of high arctic geese



Kate Layton-Matthews<sup>1</sup>, Vidar Grøtan<sup>1</sup>, Brage Bremset Hansen<sup>1</sup>, Maarten Loonen<sup>2</sup>

<sup>1</sup>Centre for Biodiversity Dynamics, Department of Biology, Norwegian University of Science and Technology, Trondheim, Norway

<sup>2</sup>Arctic Centre, University of Groningen, Groningen, Netherlands

## Background

Density dependence regulates population dynamics through negative feedbacks on population growth, this regulation can be complicated by interactions with the other extrinsic and intrinsic factors. For instance, a population's age structure can alter the nature of relationships between vital rates, density and environmental factors<sup>2</sup>. This analysis presents the temporal dynamics of arctic migratory barnacle geese, *Branta leucopsis* and summarises preliminary work on the age-specific responses to density dependence.

23 years of individual-based data (1990–2012) were collected in Kongsfjorden, western Svalbard (fig.1), constituting the summer breeding grounds of a barnacle goose population that settled in the 1980s. This population expanded until reaching carrying capacity in 2000 and has since been in a slow decline (fig. 6). Offering the unique opportunity to model population dynamics of a long-lived avian species (24 years), under different density conditions and in the rapidly changing arctic ecosystem.

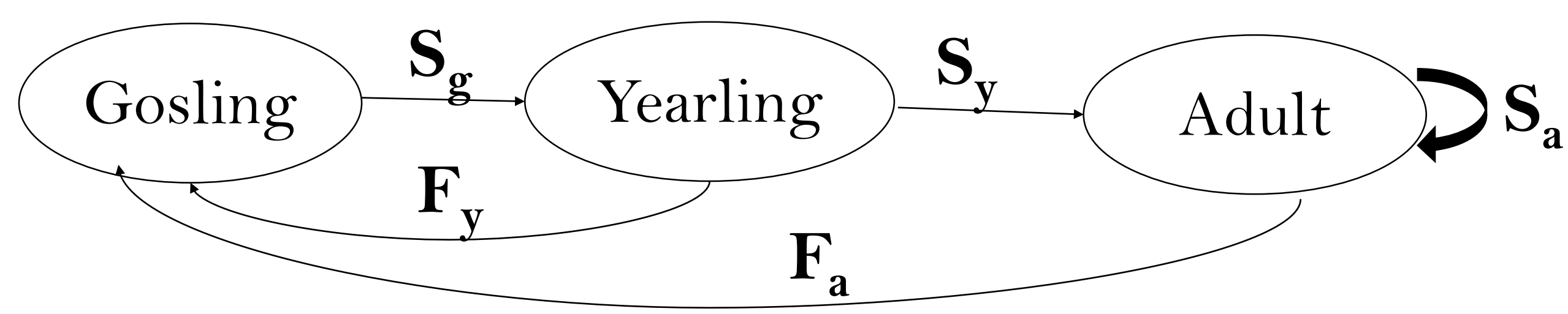


Fig 2. Life cycle describing a post breeding, age-structured model of vital rates.  $S_x$  is the probability of a female in stage  $x$  surviving until the next census,  $F_x$  is the stage specific recruitment rate, defined as the number of daughters recruited per breeding female

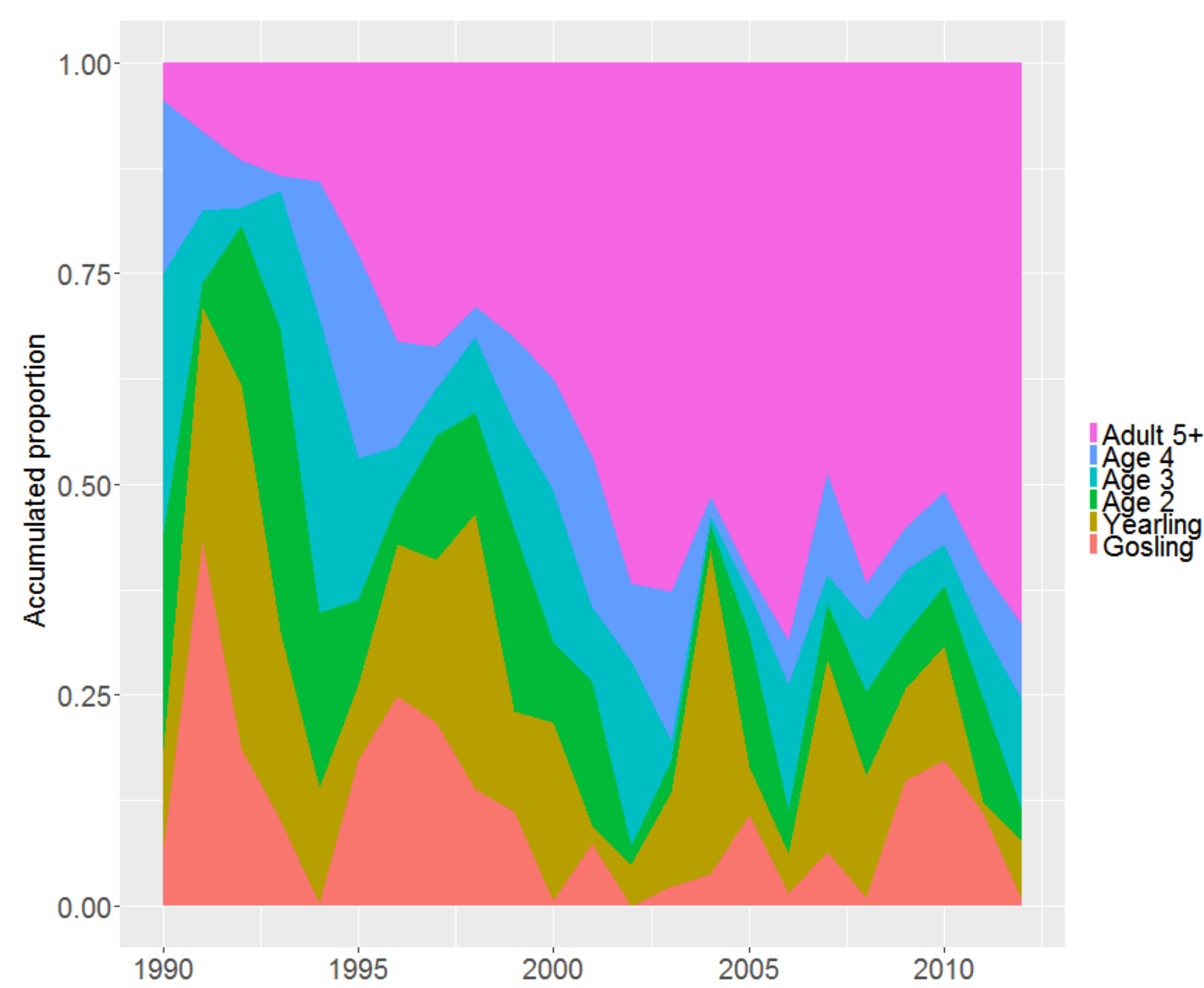


Fig 3. Temporal changes in population age structure for ages 0, 1, 2, 3, 4, 5 onwards, illustrating the progression of individuals to older ages classes (5+).

- Large age-specific, temporal variation in survival, with a strong decline in gosling survival (fig. 4)
- High inter-annual variability in fecundity and population size (fig. 5 & 6)
- Without accounting for environmental drivers or trophic interactions, using simple linear regressions we showed a significant decrease in fecundity and population growth with population size at the previous time step (fig. 8 & 9)
- Survival also decreased but non-significantly (fig.7) but this may be attributed to separation into only three age classes.

## Conclusions and next steps

- In this preliminary analysis, we observe clear signs of density dependence (figs. 7 –9), even without accounting for climate, trophic interactions and age structured fluctuations
- Thus, density dependence is likely to have contributed to the levelling off and recent negative trend in population size
- The next step will be to disentangle the contribution of different intrinsic and extrinsic drivers of population growth, as well as their interaction effects

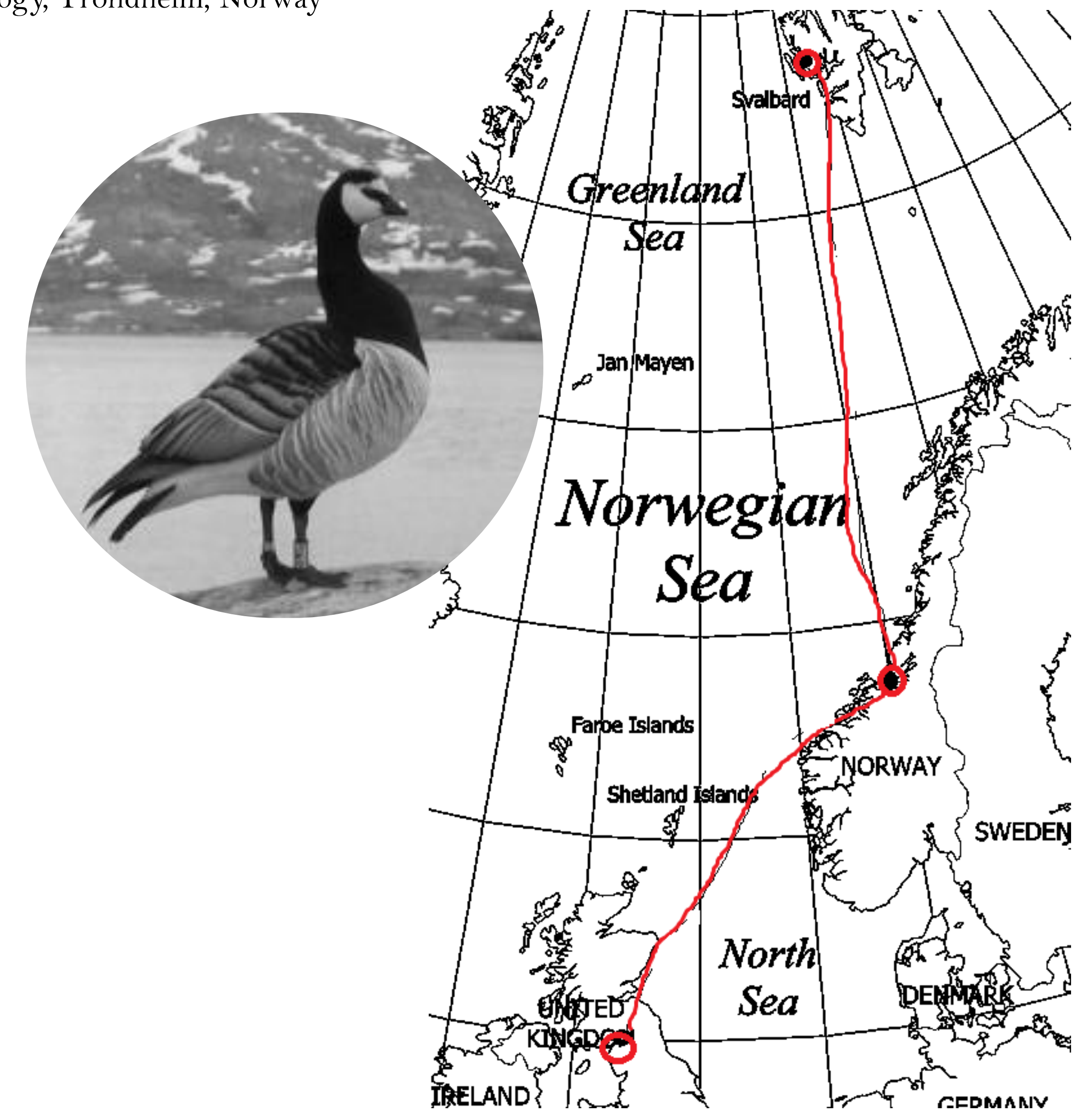


Fig 1. Map with approximate migratory route from Scotland to Svalbard via Helgeland, Norway

## Life cycle

Barnacle geese form monogamous breeding pairs and initiate nesting soon after their arrival on Svalbard. An age-structured life cycle of the barnacle goose is shown in fig. 2, Survival of goslings is heavily dependent on fox abundance (the main predator)<sup>1</sup>. We modelled age-specific survival (fig.4) and fecundity (fig.5) and made a preliminary assessment of the effect of negative, first order density dependence.

## Temporal dynamics

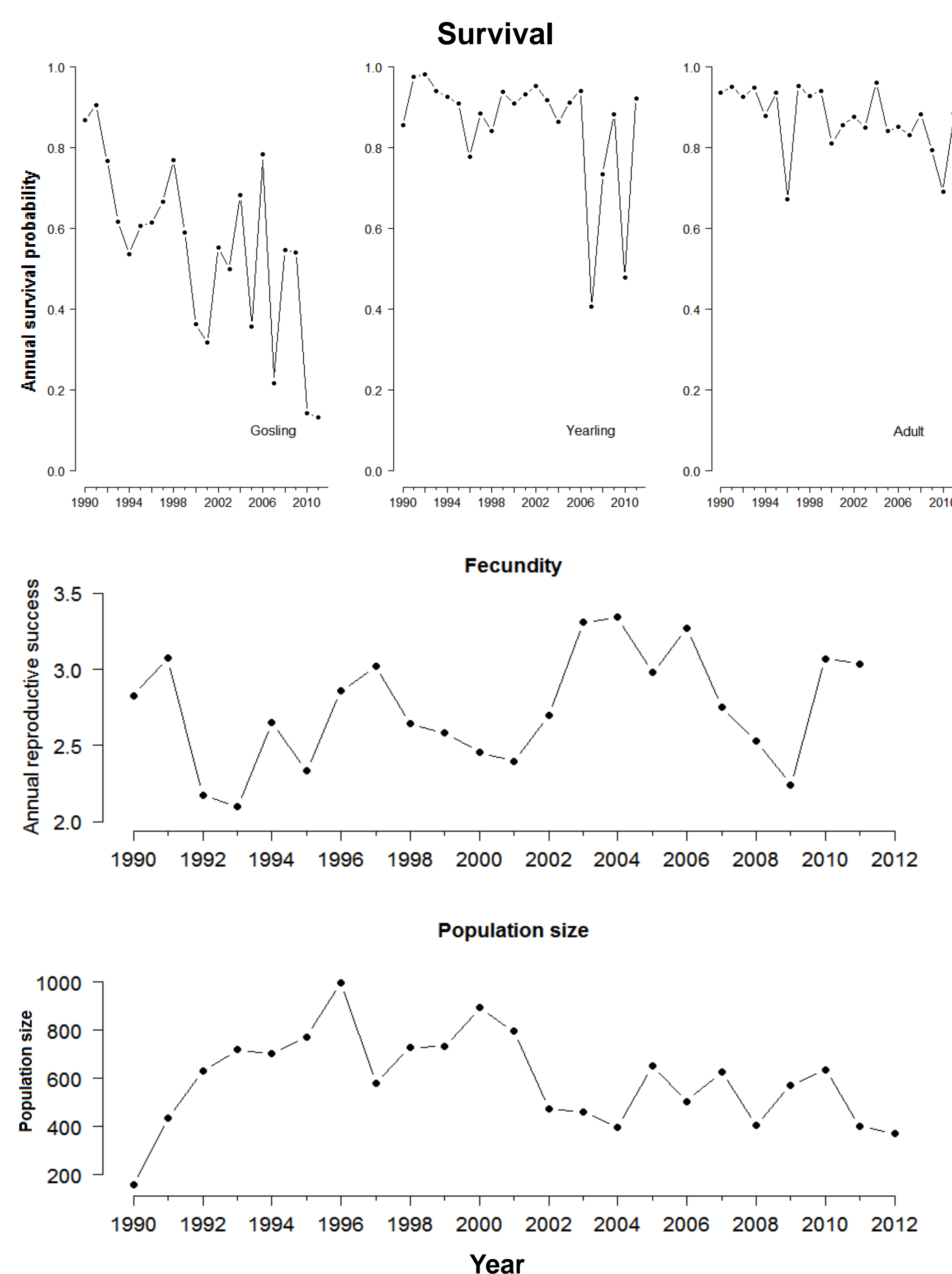


Fig. 4–6  
(4) Mean estimates of survival from 1990–2012 for a) goslings b) yearlings and c) adults  
(5) Number of daughters per reproducing female  
(6) Annual number of ringed individuals in Kongsfjorden

## Density dependence

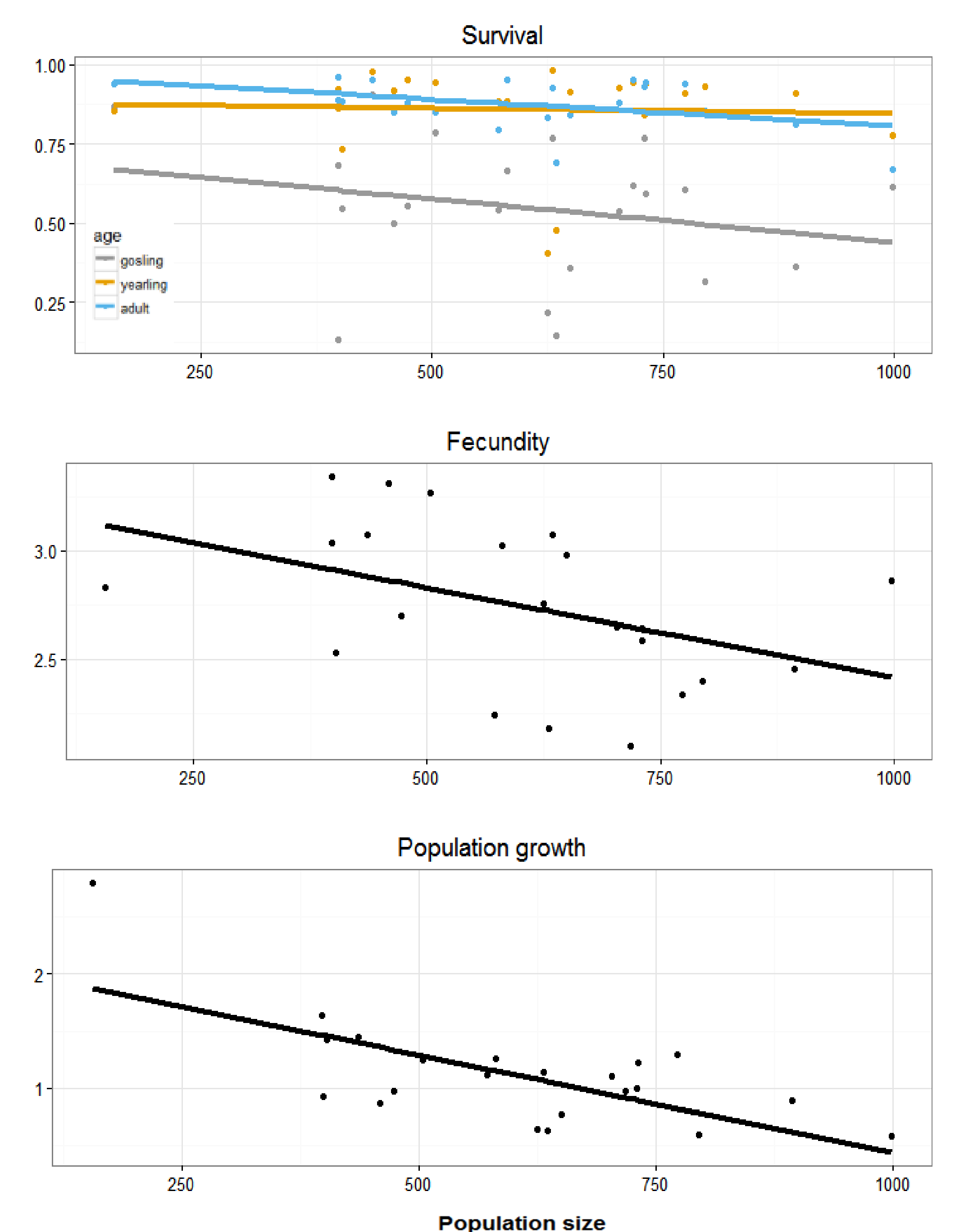


Fig. 7–9  
(7) Age-specific survival at time  $t-t+1$  against population size at time  $t$   
(8) Fecundity at time  $t-t+1$  against population size at time  $t$   
(9) Population growth rate at  $t-t+1$  against population size at time  $t$   
Points correspond to the data from fig. 4–6

## References

- <sup>1</sup>Stahl, J. U. L. I. A., and M. J. J. E. Loonen. "The effects of predation risk on site selection of barnacle geese during brood-rearing." *Skrifter-Norsk Polarinstitutt* (1998): 91–98.  
<sup>2</sup>Coulson, Tim, et al. "Age, sex, density, winter weather, and population crashes in Soay sheep." *Science* 292.5521 (2001): 1528–1531.  
Photo credit: Maarten Loonen, 2005.